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The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018)

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A decade ago, scientists and practitioners working in environmental water management crystallized the progress and direction of environmental flows science, practice, and policy in The Brisbane Declaration and Global Action Agenda (2007), during the 10th International River*symposium* and International Environmental Flows Conference held in Brisbane, Australia. The 2007 Declaration highlights the significance of environmental water allocations for humans and freshwater-dependent ecosystems, and sets out a nine-point global action agenda. This was the first consensus document that bought together the diverse experiences across regions and disciplines, and was significant in setting a common vision and direction for environmental flows internationally. After a decade of uptake and innovation in environmental flows, the 2007 declaration and action agenda was revisited at the 20th International River*symposium* and Environmental Flows Conference, held in Brisbane, Australia, in 2017. The objective was to publicize achievements since 2007 and update the declaration and action agenda to reflect collective progress, innovation, and emerging challenges for environmental flows policy, practice and science worldwide. This paper on The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018) describes the inclusive consultation processes that guided the review of the 2007 document. The 2018 Declaration presents an urgent call for action to protect and restore environmental flows and aquatic ecosystems for their biodiversity, intrinsic values, and ecosystem services, as a central element of integrated water resources management, and as a foundation for achievement of water-related Sustainable Development Goals (SDGs). The Global Action Agenda (2018) makes 35 actionable recommendations to guide and support implementation of environmental flows through legislation and regulation, water management programs, and research, linked by partnership arrangements involving diverse stakeholders. An important new element of the Declaration and Action Agenda is the emphasis given to full and equal participation for people of all cultures, and respect for their rights, responsibilities and systems of governance in environmental water decisions. These social and cultural dimensions of e-flow management warrant far more attention. Actionable recommendations present a pathway forward for a new era of scientific research and innovation, shared visions, collaborative implementation programs, and adaptive governance of environmental flows, suited to new social, and environmental contexts driven by planetary pressures, such as human population growth and climate change.

Keywords: environmental water, social-ecological systems, climate change, resilience, Sustainable Development Goals (SDGs), The Brisbane Declaration (2007)

INTRODUCTION

The deteriorating condition of riverine and wetland ecosystems and loss of freshwater biodiversity resulting from water infrastructure impacts, water extraction, and altered flow regimes has led to the field of environmental flows. The science and practice of environmental flows has a long history of achievements as an approach to protect and recover aquatic biodiversity, ecosystem integrity and important ecological services by managing freshwater flow regimes. Reflecting on the past 25 years of this history, Poff and Matthews (2013) nominated The Brisbane Declaration (2007) on environmental flows as a pivotal statement and synthesis. This document brought together the diverse experiences of environmental flows practitioners across regions and disciplines, and set a common vision and direction for environmental flows internationally. The 2007 Declaration was formulated during the 10th International River*symposium* and International Environmental Flows Conference held in Brisbane, Australia, and endorsed by 800 delegates from more than 50 countries. The accompanying nine-point Global Action Agenda called upon "*all governments, development banks, donors, river basin organizations, water and energy associations, multilateral and bilateral institutions, community-based organizations, research institutions, and the private sector across the globe to commit to a suite of actions for restoring and maintaining environmental flows.*"

The Brisbane Declaration (2007) provided evidence of the global dimensions of freshwater ecosystem degradation and its links to human water security. It highlighted the vital importance of environmentally sustainable water resources management, and provided a widely recognized definition of environmental flows (sometimes termed e-flows) as *"the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems."* This definition has since been cited in over 30 scholarly books and hundreds of journal publications and reports, testifying to the value of a consolidated, widely accepted statement of the essence and vital purpose of environmental flows. The Declaration embraced an environmental flows approach based on the natural flow regime (Poff et al., 1997), and stimulated a further decade of research and practice focused on aquatic ecosystem protection, restoration and management. Numerous, diverse water and environment research and development projects, as well implementation initiatives, have tested and strengthened the scientific basis of environmental flows on-the-ground (reviewed in Horne et al., 2017c; Poff et al., 2017). Many have also expanded the scope of assessments from individual sites to whole river basin and regional scales (e.g., King and Brown, 2010; Buchanan et al., 2013; Hart, 2016a,b; O'Brien et al., 2017; Stein et al., 2017). Reflecting these developments, investments in large scale, collaborative e-flow strategies and experiments are increasing across developed and developing regions (e.g., Hirji and Davis, 2009; Konrad et al., 2011; Olden et al., 2014; Hart, 2016a,b; Kendy et al., 2017; Kennen et al., 2018). Parallel efforts have revitalized governance and management arrangements (Foerster, 2011; Pahl-Wostl et al., 2013; Garrick et al., 2017), and promoted multi-stakeholder alliances across researchers, water management agencies, industry, non-government organizations (NGOs), civil society and indigenous groups (Le Quesne et al., 2010; Conallin et al., 2017). Furthermore, environmental water requirements have been incorporated into high-level policies and platforms for river health and catchment management, such as Motion M087 (IUCN, 2012), Resolution XII.12 (Ramsar, 2015) and the European Union Water Framework Directive (European Commission, 2015). Many countries now formally protect and manage environmental water through national laws and regulations, as well as at the basin scale (e.g., King and Pienaar, 2011; Grafton et al., 2012; O'Donnell, 2014).

Fast-forward 10 years to the 20th International River*symposium* and Environmental Flows Conference, held in Brisbane in September 2017. A programme highlight was the celebration of progress with environmental flows since The Brisbane Declaration (2007), and renewal of this influential document to reflect recent developments and emerging challenges. Whilst progress with environmental flows science and water management since 2007 has been immense, major challenges remain in protecting and restoring the integrity of freshwater ecosystems and the ecological services that sustain human cultures, economies, livelihoods, and well-being (e.g., Arthington, 2012; Rockström et al., 2014; Hart and Doolan, 2017; Horne et al., 2017b; Kennen et al., 2018). Environmental flow requirements have still not been adequately assessed for most aquatic ecosystems and have been implemented in even fewer (Moore, 2004; Le Quesne et al., 2010; Gillespie et al., 2015; Harwood et al., 2017). In fact, in spite of admirable global efforts, there is no single global record of environmental flow implementations, nor a good understanding of why some projects have succeeded, while other initiatives have failed even to get off the ground. Major obstacles to environmental flow implementation (elaborated by Moore, 2004; Le Quesne et al., 2010; Harwood et al., 2017) include: lack of political will and public support; constraints on resources, knowledge and capacity; and, institutional barriers and conflicts of interest. For these and other reasons the condition of aquatic ecosystems continues to decline while the pressures continue to grow (Vörösmarty et al., 2013; Bunn, 2016; Reis et al., 2017; Degefu et al., 2018). The world is experiencing a renewed period of dam building driven by new donors and applying different social and environmental safeguards (Zarfl et al., 2015; Greenhill et al., 2016; Kirchherr et al., 2016). Moreover, much of the new construction is concentrated in ecologically sensitive river basins where dams will act as barriers to fish and other migrations, and fragment formerly connected populations (Winemiller et al., 2016; Anderson et al., 2018). Globally, 48% of river volume is moderately to severely impacted by either flow regulation, fragmentation, or both, and this proportion will nearly double if all dams planned and under construction are completed (Grill et al., 2015). Water demands continue to grow in most parts of the world, including semi-arid regions already experiencing medium to high water stress (Luck et al., 2015; Datry et al., 2017). All signs point to increased flow alteration in coming decades and less water for the environment overall. The urgency for implementation of environmental flows is thus greater than ever.

The framing of environmental flows is also transitioning to accommodate increasing uncertainties associated with hydro-climatic and ecological variability (Milly et al., 2008; Poff, 2018; Capon et al., in review), and new societal contexts. Wider appreciation of the social and cultural implications of environmental water and healthy aquatic ecosystems for human riparian communities is an important advance (Johnston, 2012; Lokgariwar et al., 2013; Jackson, 2017). These emerging factors demand new perspectives, renewed research effort, and innovation beyond established approaches to the science and management of water for the environment (Kennen et al., 2018; Poff, 2018; Stoffels et al., 2018; Thompson et al., 2018; Webb et al., 2018). There is also the recognition that there are many flow regime options for a river beyond trying to restore the natural or historical flow regime (e.g., Acreman et al., 2014b; Bond et al., 2014; Poff et al., 2017). Further, choosing between options requires a clear articulation of visions and goals, as well as a capacity to predict the expected outcomes (physical, ecological, societal, economic) from each environmental flow strategy.

With these new perspectives and options on the agenda, this is an opportune moment in the history of environmental flows to build on insights of the 2007 Declaration, a decade on, and re-state the need for more action on water for the environment in all its dimensions. Furthermore, the emphasis of the Sustainable Development Goals (SDGs; UN, 2015) on protecting freshwater and coastal ecosystems could build further momentum for environmental flows to be repositioned as a central element of sustainable water resources management.

The overall objective of this paper is to re-emphasize the pressing need for a more committed effort to protect and restore freshwater ecosystems as resilient social-ecological systems through implementation and adaptation of environmental flows. The paper has four main elements, framed around the development and content of The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018), which is presented in full as Appendix 1.

First, the paper chronicles the inclusive consultation processes employed to gather advice on renewal of The Brisbane Declaration (2007). This section summarizes the thrust of the changes recommended by symposium delegates, and numerous colleagues contacted through professional networks before, during, and after River*symposium* 2017. It also notes some of the suggestions that were not included (e.g., change the term environmental flows to environmental water; provide more detail on linkages and synergies with water-related SDGs), and why it was felt that they could not be incorporated at this time. The main elements of the revised declaration form the second section, which also explains the rationale behind the refined definition of environmental flows and the renewed declaration statements. The third element outlines the Global Action Agenda 2018, setting out over 30 actionable recommendations linked to each declaration statement under three categories of activity (viz. leadership and governance, management, and research). The intent of the actions is to map a pathway forward for a new era of scientific research and innovation, shared visions, collaborative implementation programs and adaptive governance of environmental flows. The 2018 Action Agenda offers ample opportunities for engagement across multiple sectors, disciplines, regions, and cultures. The final section briefly describes future plans for the dissemination and uptake of the renewed document, through global agencies, professional networks, social media, interviews, publications and other follow-up activities. Further, The Brisbane Declaration and Global Action Agenda (2007) is appended as part of the historic record (Appendix 2).

ASSESSMENT OF ENVIRONMENTAL FLOWS POLICY AND GUIDELINES

Consultation on The Brisbane Declaration (2007)

This assessment of environmental flows policy and guidelines is focused on a review of the Brisbane Declaration and Action Agenda (2007) by means of comprehensive consultation processes, and consideration of relevant literature. As a first step, The Brisbane Declaration (2007) was presented for open discussion and critique by a multi-institutional, multi-disciplinary group of social scientists, ecohydrologists and practitioners in an international workshop convened at the National Socio-Environmental Synthesis Center, Annapolis, Maryland, USA, in June 2017. This led to several recommendations on the potential format and content of a revised declaration and action agenda. Secondly, the 2007

Declaration and Action Agenda was placed on a dedicated social media website (https://www.linkedin.com/feed/update/urn:li:activity:6305898179577679872/) with an invitation to all River*symposium* 2017 delegates to offer comment, and suggest changes and additions to enhance the text. Numerous other colleagues were also invited to comment over a 6-month period (2017–2018). A first (2017) draft of the renewed declaration was produced through this consultation phase and posted on social media during the month preceding River*symposium* 2017. Delegates to the symposium were invited to contribute further comments during the 3 days of symposium. A first draft of The Brisbane Declaration on Environmental Flows (2018) was endorsed in principle by delegates at River*symposium* 2017 and numerous colleagues who were unable to attend the event. A second draft of the declaration and first draft of the action agenda were posted for comment, and a further phase of consultations, followed by consolidation of the text by the authors of this paper, produced the final version—The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018)—presented in Appendix 1.

Comments on the 2007 Declaration were diverse and informative, ranging across the definition of environmental flows, the purpose, audience, structure, content and tone of the declaration, the scope and details of the action plan, and the need for supporting documentation (e.g., literature citations). Major points are discussed in turn below, noting, as well, the suggestions that were not included, and how they could be addressed in future (e.g., as elements of projects proposed in the Global Action Agenda).

Definition of Environmental Flows

The definition of environmental flows expressed in the 2007 Declaration attracted many suggestions, the most extreme being to replace the term "environmental flows" with "environmental water" or "water for the environment." Some colleagues suggested that this terminology would convey the intent to include lotic systems (i.e., all freshwater and coastal ecosystems supported by flowing water), lentic systems (i.e., standing water ecosystems such as wetlands and lakes fed by surface or groundwater but not linked to or fed by lotic systems) and groundwater-dependent ecosystems (GDEs). There is merit in the general term "environmental water" (a water volume) instead of environmental flow (a discharge), to embrace the broad ranging treatment of environmental water issues profiled in the recent text *"Water for the Environment: From Policy and Science to Implementation and Management"* (Horne et al., 2017c). Other terminology also has appeal; for example, the European Commission (2015) defines "ecological flows" in terms of "hydrological regimes" to halt the ecological deterioration of aquatic systems and achieve good ecological status. The 2018 Declaration strongly supports the call to embrace all surface and groundwater-dependent aquatic ecosystems, whether flowing or standing, into the science and management of freshwater environmental flows. In the authors' view, ceasing to use the widely accepted term "environmental flows" at this juncture could disconnect the 2018 Declaration from the 2007 Declaration, as well as from the vast body of environmental flows knowledge and implementation experience published before and since 2007.

To maintain continuity of the terminology while broadening the scope to embrace all aquatic ecosystems and their coupled human systems dependent upon flowing, standing or ground water, the 2018 Declaration includes the following definition: "*Environmental flows describe the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems[a] which, in turn, support human cultures, economies, sustainable livelihoods, and well-being."* In this definition, "*Aquatic ecosystems include rivers, streams, springs, riparian, floodplain and other wetlands, lakes, coastal waterbodies, including lagoons and estuaries, and groundwater-dependent ecosystems*" (Appendix 1). By altering the original wording from "*..quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems.."* to "*quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems[a]"*, the revised definition meets the call to embrace flowing (lotic), standing (lentic) and GDEs, as well as aquatic ecosystems that may alternate between these states (e.g., ephemeral streams and intermittent rivers). The management of ponds, wetlands, and lakes involves consideration of water volumes, levels and residence time (e.g., Nakamura and Rast, 2011), groundwater connections, and overland flows. The use of the more inclusive concept of environmental flows and the terms "flows and levels" are intended to accommodate such attributes. The expanded scope of the environmental flows definition also includes GDEs of the three main types identified by Richardson et al. (2011) and others (Boulton and Hancock, 2006; Eamus and Froend, 2006). These include aquifer and cave systems; "ecosystems fully or partly dependent on the surface expression of groundwater including wetlands, lakes, seeps, springs, river baseflow, coastal areas, estuaries, and marine ecosystems"; and "ecosystems dependent on subsurface presence of groundwater (via the capillary fringe), including terrestrial vegetation that depends on groundwater fully or on an irregular basis to meet water requirements." Environmental flow management must address the lotic, lentic and groundwater phases of all freshwater-dependent aquatic ecosystems, including their riparian and basin surroundings, to sustain their ecological integrity, ecosystem services and societal values (Bunn, 2016; Datry et al., 2017; Gleeson and Richter, 2017; Horne et al., 2017c; Kennen et al., 2018). To achieve a more integrated approach that considers the water requirements of inter-connected surface and GDEs will be one of the next grand challenges of environmental flows science and management.

A frequent comment on the 2007 definition of environmental flows pertained to the critical recognition of linkages between "*freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems*" (The Brisbane Declaration 2007, Appendix 2). Respondents recommended more explicit reference to the dependence of "*human cultures, economies, sustainable livelihoods, and well-being*" on healthy, resilient freshwater-dependent ecosystems and the role of environmental flows in the lives of people of all cultures. This shift of emphasis is consistent with the recognition that sustaining aquatic ecosystem health and resilience is the foundation for achieving human water security and flourishing livelihoods, for all societies in all regions and across all economic realms (Richter et al., 2010; Vörösmarty et al., 2013; UN, 2015). It encompasses the breadth of relationships from riparian communities dependent on healthy rivers for subsistence livelihoods, including smallholder farmers and fishers, through to societies with complex agricultural water infrastructure controlled under centralized and hierarchical governance arrangements. The statement of peoples' dependencies on and responsibilities toward healthy aquatic ecosystems is in line with the United Nations (UN) Sustainable Development Agenda 2030 and its SDGs and targets (UN, 2015), all of which promote wise use of water, other natural resources and global life support systems (e.g., Bhaduri et al., 2016; Garrick et al., 2017). However, it is also fully recognized that direct use of fresh water is essential for human survival, as specified in the SDGs. Nevertheless, certain conservation values and ecosystem services can still be provided by aquatic ecosystems with modified water regimes. How to decide which values, features and services should be retained or restored is a major dimension of environmental flows.

Links to Sustainable Development Goals

A clear message from consultations was to articulate how environmental flows could contribute to the achievement of the United Nations Sustainable Development Agenda 2030 and the SDGs and targets (UN, 2015). This UN framework presents a "*bold and transformative agenda in support of the twin challenge: protection of Earth's life-support system while reducing hunger and poverty*" (Jägermeyr et al., 2017). Water flows through and underpins all of the SDGs, notably but not only Goal 6 (Ensure access to water and sanitation for all), which includes targets to improve water quality by reducing pollution (6.3), and to protect and restore water-related ecosystems including rivers, wetlands, aquifers, and lakes (6.6, 15.1). Environmental water requirements are explicitly referenced and defined in SDG indicators 6.4.2 (Level of water stress) and 6.6.1 (Change in the extent of water-related ecosystems over time). Environmental flows contribute to improvements in the production of freshwater and estuarine foods such as fisheries (14.2), thereby contributing indirectly to SDGs 1 (no poverty), SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 8 (decent work and economic growth), SDG 12 (sustainable management and efficient use of natural resources), and SDG 16 (peaceful and inclusive societies for sustainable development, and access to justice for all). There are similar links between environmental flows and energy production, cities and other priorities within the SDG portfolio. These direct and indirect linkages and dependencies flow through to the 2018 Global Action Agenda as recommendations for leadership and governance, management, and research activities to integrate environmental flows into programs to achieve SDGs. A fuller articulation of these linkages and dependencies of environmental flows and healthy ecosystems with achievement of the SDGs was recommended during consultations. However, the authors felt that these inclusions were beyond the scope of the 2018 Declaration and Global Action Agenda, and this paper. This type of analysis could form an important future project.

Linkages With Other Resolutions and Declarations

Another suggestion was that the Declaration should build linkages with many other resolutions and declarations (going back to the *Rio Declaration on Environment and Development* 1992, and including, for example, declarations made on water by Indigenous Peoples at the World Water Forums), or at least list them in the document. A long list emerged, however, lacking the space to provide an adequate discussion of linkages and the benefits to be derived from such an exercise, this idea was not developed further. Three particularly relevant water-related policies and platforms for river health and catchment management are mentioned above (Motion M087, IUCN, 2012; Resolution XII.12, Ramsar, 2015; European Union Water Framework Directive, European Commission 2015).

2018 Declaration on Environmental Flows

The main narrative of the 2018 declaration is contained in six statements and the associated amplifying text (Appendix 1). In summary, the core messages are that environmental flows are essential to protect and restore freshwater-dependent aquatic ecosystems, and to deliver important and wide-ranging ecological services that, in turn, support cultures, economies, sustainable livelihoods, and well-being. Environmental flows have been compromised or are at risk in most aquatic systems around the world, and the cumulative global impacts on biodiversity, aquatic ecosystem health, ecological services, and society are severe (Dudgeon et al., 2006; Vörösmarty et al., 2015; Bunn, 2016). However, judicious use of water to better balance human and ecological needs can support biodiversity, resilient ecosystems, and socially-valued ecological services, including those provided by modified and novel aquatic ecosystems (Acreman et al., 2014b; Poff et al., 2016). There is ample evidence that concerted efforts to provide environmental flows can lead to societal and ecological outcomes that are socially acceptable and economically beneficial (e.g., King and Brown, 2010; Hermoso et al., 2012; Chen and Olden, 2017; Harwood et al., 2017). Implementation of environmental flows requires a complementary suite of policy, legislative, regulatory, financial, scientific, and cultural norms and values that ensure effective delivery and beneficial ecological and societal outcomes (Hart, 2016a,b; Harwood et al., 2017; Horne et al., 2017c). The full and equal participation of people of all cultures, and respect for their rights, responsibilities and systems of governance in environmental water decisions can strengthen sustainable outcomes, and these social and cultural dimensions of e-flow management warrant far more attention (Richter et al., 2010; Johnston, 2012; Vörösmarty et al., 2013; Taylor et al., 2016). Challenges to environmental flows science and practice are emerging as societal perspectives shift due to increased uncertainty about water availability under growing human demand and climate change (Milly et al., 2008; Poff and Matthews, 2013; Capon et al., in review). It is anticipated that more variable water regimes and changing patterns of human use will increase the risk of aquatic ecosystem degradation, and intensify the urgency for action to implement optimal water management solutions from human and environmental perspectives (Humphries and Winemiller, 2009; Rockström et al., 2014; Bunn, 2016). To address these issues comprehensively and globally requires more recognition, effort, innovation, commitment, and above all concerted implementation actions, to achieve beneficial outcomes from environmental flows and wise freshwater management for people, biodiversity and ecosystems.

ACTIONABLE RECOMMENDATIONS ON ENVIRONMENTAL FLOWS

The Global Action Agenda on Environmental Flows (2018)

A strong message from the consultations was that actions should be matched to the declaration statements and tailored to particular themes and groups of actors. Drawing upon several sources (e.g., Bunn, 2016; Hart, 2016a,b; Harwood et al., 2017; Horne et al., 2017a,b,c), actions in the 2018 Declaration are organized under three main categories (viz., leadership, management, and research) as summarized in Appendix 1 (**Table A1**).

In this scheme "Leadership and Governance" involves relevant levels of government (international, national, provincial, regional, local) in the development of legislation, policies, regulations and funding mechanisms to institutionalize, promote, and support e-flow science and management within the broader context of jurisdictional natural resource management. Other stakeholders, including civil society and the private sector, can influence governments to lead the development of appropriate instruments.

"Management" involves processes of planning, assessment, implementation, monitoring, and adaptive management of environmental flows by relevant parties including, for example, transboundary, national, and regional water agencies, basin organizations, large water users, NGOs, researchers, cultural groups, indigenous organizations, and other stakeholders (Harwood et al., 2017).

"Research" was added to these two categories to emphasize the ongoing need for deeper investigation of environmental flow issues across the full spectrum of the environmental water management cycle. This cycle ranges from setting a vision for each environmental flow project, to assessing environmental flow requirements and implementing an environmental water plan, to monitoring and evaluating outcomes and adjusting the vision or plan accordingly (Horne et al., 2017a).

Engagement of trans-disciplinary researchers and stakeholders in co-development, partnership or advisory roles is recommended within both the leadership and the management arenas of activity (Conallin et al., 2017). For example, researchers may engage with national, provincial, and local governments to help guide policy development, as seen in several countries (e.g., Australia, South Africa, the European Union). Partnership arrangements with water management agencies can help to guide and monitor environmental flow assessments, and working with NGOs, citizens and indigenous decision-makers is important to integrate scientific and local cultural knowledge of aquatic ecosystems. Models that inform such partnership arrangements abound, each with individual scope, structure and promise of successful outcomes (Jackson et al., 2014; Conallin et al., 2017; Harwood et al., 2017; Stoffels et al., 2018).

The Global Action Agenda (2018) is necessarily brief, reflecting advice from the consultations, and the fact that several recent works have set out detailed statements and summaries of actions needed to advance environmental flows governance, science, implementation and management. As well as Harwood et al. (2017), these include the recent book "*Water for the Environment*" (Horne et al., 2017c), synthesis papers from several special journal issues devoted to environmental flows science and management (Acreman et al., 2014a; Bunn, 2016; Arthington et al., 2018; Kennen et al., 2018; Webb et al., 2018), and a paper setting out the results of a survey of important research priorities to inform future environmental water outcomes (Horne et al., 2017b). The summary of actions in Appendix 1 is less detailed but consistent with the main recommendations of these works.

Actions set out in Appendix 1 also reflect the Global Action Agenda (2007), which emphasized immediate action to: estimate environmental flows (integrated with water quality) and embed environmental flow management in programs and strategies for land-use, water-use, and energy-production; implement and enforce environmental flows; establish institutional frameworks; actively engage all stakeholders; identify and conserve a global network of free-flowing rivers; build capacity; and learn by doing (Appendix 2). Whilst there is ample evidence of progress against each of these actions items (discussed above, and recorded in the cross-section of publications cited herein), this decadal review of progress suggests that a broader scope and explicit action recommendations would add weight to the Global Action Agenda (2018) and should encourage progress in many dimension of environmental flows.

New elements of the Global Action Agenda (2018) include actions to address the direct and indirect relevance and contributions of environmental flows to the achievement of water-related SDGs, the attention directed to recognition, respect for, empowerment and engagement of diverse cultures and communities; and the framing of environmental flows in new global contexts, particularly the implications of climate change. The latter include the implications for water quality, availability, and security, as well as the societal, economic and ecological consequences of shifting climatic and other environmental regimes. Rapid population growth, new geographic patterns of human (and other biological communities), and climate change risks compound the challenges of environmental flow management and ecosystem sustainability (Capon et al., in review). Flow regimes and ecological baselines are changing in many ecosystems and novel ecosystems are emerging, each with implications for riparian cultures, economies and human well-being (Humphries and Winemiller, 2009; Acreman et al., 2014b; Rockström et al., 2014; Poff, 2018). These changes herald a new era of environmental flows science, assessment and management, one that seeks to adapt traditional approaches and methods to the realities of climatic and other environmental changes, ecosystem adjustments, and societal consequences (Poff, 2018; Thompson et al., 2018; Capon et al., in review).

The renewed Action Agenda promotes leadership to implement governance processes for adapting environmental flow management to climate change and human use scenarios, innovation around existing and novel technologies, and further application of trade-off processes to balance ecological resilience and societal benefits, including those provided by ecosystems with modified water regimes (e.g., Hermoso et al., 2012; Poff et al., 2016; Cartwright et al., 2017; Chen and Olden, 2017). Finally, long-term studies of aquatic ecosystem adjustments and societal responses are recommended in climatic and environmental change hotspots using novel experimental designs, meta-data analysis and measurement of ecological variables that capture rates of change in relation to shifting environmental flows, water quality and human water use (Davies et al., 2014; Arthington et al., 2018; Webb et al., 2018). Strengthening scientific understanding and evidence of the different benefits of environmental flows for ecosystems, economies and people under emerging planetary pressures is essential to guide water management toward social- ecological resilience in the future.

Dissemination of the 2018 Declaration and Global Action Agenda

Global dissemination of the final version of the 2018 Declaration presented in Appendix 1 is encouraged through international agencies (e.g., FAO, UNESCO, UNDP, UNEP, Ramsar, WHO), national governments, land and water management agencies, river basin groups, NGOs, professional networks, social media and key fora (e.g., World Water Forum 2018, Brazil, and World Water Week, Stockholm, 2018). Opportunities abound for tracking uptake of renewed Brisbane Declaration (2018), and assessing progress with implementation structured around the Action Agenda. Examples include postgraduate studies, systematic literature reviews, collaborative research and solution laboratories, and projects designed to support achievement of water-related SDGs.

CONCLUSIONS

The Brisbane Declaration and Action Agenda (2007) on environmental flows brought together the diverse experiences of environmental flows practitioners across regions and disciplines, and set a common vision and direction for environmental flow science and management internationally. It provided evidence of the global dimensions of freshwater ecosystem degradation and its links to human water security, and stimulated a decade of research, engagement, and action to protect and restore aquatic ecosystems by means of freshwater flow management. However, in spite of significant progress, environmental flow requirements have still not been adequately assessed for most aquatic ecosystems, and have been implemented in even fewer. All signs point to growing demands for fresh water, increased water stress, more flow regulation, and fragmentation of aquatic habitats, and less water for the environment overall in coming decades. Thus the urgency for implementation of environmental flows, monitoring their social-ecological outcomes and supportive research, is greater than ever. To address these issues comprehensively and globally requires more recognition, effort, innovation, commitment, and above all concerted implementation actions, to achieve beneficial outcomes from environmental flows and wise freshwater management for people, biodiversity and ecosystems. The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018) provides over 30 actionable recommendations to support and advance environmental flow implementation. It heralds a new era of scientific innovation, shared visions, collaborative implementation programs and adaptive governance of environmental flows, with ample opportunities for engagement across multiple sectors, disciplines, regions, and cultures. Working together in a more committed, organized, and inclusive manner to reposition environmental flows as a central element of sustainable water resources management in changing landscapes, climates, and scenarios of water security is now more urgent than ever. Furthermore, the emphasis of the SDGs on protecting freshwater and coastal ecosystems could build further momentum for environmental flows to be repositioned as a central element of sustainable water resources management.

AUTHOR CONTRIBUTIONS

All authors contributed to drafting The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018) and to the preparation of this paper.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDIX 1

The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018)

The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018) was developed and endorsed by a fast growing international network of environmental flow practitioners comprising civil society, indigenous peoples, the private sector, scientists, water users, businesses, non-government organizations, local, regional and national government agencies, and international institutions. This declaration builds on and supplements the influential Brisbane Declaration and Global Action Agenda (2007) developed a decade earlier during the 10th *International Riversymposium and International Environmental Flows Conference* held in Brisbane, Australia, September 2007. The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018) was endorsed by delegates of the 20th *International Riversymposium and Environmental Flows Conference* (Brisbane, September 2017) and numerous colleagues.

Environmental flows describe the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being. In this definition, *aquatic ecosystems* include rivers, streams, springs, riparian, floodplain and other wetlands, lakes, freshwater dependent coastal water bodies, including lagoons and estuaries, and groundwater-dependent ecosystems (GDEs). The goal of environmental flow management is to protect and restore the socially valued benefits of healthy, resilient, biodiverse aquatic ecosystems and the vital ecological services, economies, sustainable livelihoods, and well-being they provide for people of all cultures.

The Brisbane Declaration on Environmental Flows (2018) presents an urgent call for action to protect and restore environmental flows and resilient aquatic ecosystems for their biodiversity, intrinsic values and ecosystem services as a central element of water resources management, and as a foundation for achievement of the water-related Sustainable Development Goals.

The Brisbane Declaration on Environmental Flows (2018)

Environmental Flows Are Essential to Protect and Restore Biodiversity, Aquatic Ecosystems, and the Ecosystem Services They Provide For All Societies

All aquatic ecosystems need a dynamic environmental flow or standing water regime to sustain their biodiversity and ecological services. Flows vary with climate, landscape factors, human influences, and through time. Flow patterns govern habitat, biodiversity, productivity and aquatic ecosystem resilience. Healthy aquatic, wetland, and riparian habitats often expand during natural wet phases but can become fragmented or diminished in size or function during natural dry phases, and as a result of human water extraction and diversion. Many functionally intact rivers connect to vast floodplains and they contribute beneficial freshwater and sediment inflows to coastal zones. These dynamic processes support important and wide-ranging ecological services that, in turn, support cultures, economies, sustainable livelihoods, and well-being.

Environmental Flows Are Critical to Protect and Safeguard the World's Cultural and Natural Heritage

The intangible spiritual attachments between people, rivers and wetlands are enduring, and the human inclination to revere rivers and celebrate symbols and rituals relating to water is universal. Many human societies ascribe meaning to water and its flow, transmitting shared understandings of the world through cultural objects and practices, including ecosystem protection. Managing environmental water sustainably is necessary to protect and restore these natural and cultural heritage values.

Environmental Flows Have Been Compromised and Today Many Aquatic Systems Around the World Are at Risk

Freshwater species continue to decline more rapidly than terrestrial and marine species, primarily due to pressures from habitat degradation, over-abstraction, pollution, poorly-planned infrastructure, and modified flows. Many new dams under construction, or proposed, will further degrade aquatic ecosystems. As freshwater ecosystems degrade and species are lost, human communities lose important social, cultural, and economic benefits; estuaries lose productivity; invasive plants and animals flourish; and the social-ecological resilience of riverine, wetlands, and estuarine ecosystems weakens. The cumulative global impact is severe. Judicious human use of water to balance human and ecological needs can support biodiversity, sustainable ecosystems, and ecological services.

Implementation of Environmental Flows Requires a Complementary Suite of Policy, Legislative, Regulatory, Financial, Scientific, and Cultural Measures to Ensure Effective Delivery and Beneficial Outcomes

Policy, legislation, and regulation on water, environment, and related sectors (e.g. agriculture, energy) are necessary to explicitly recognize, protect, and support the provision of environmental flows according to context. The determination, delivery, and evaluation of environmental flows should be based on scientific and cultural knowledge collected and analyzed within an adaptive management framework that balances human water requirements and water for ecosystems. Implementation of environmental flows requires adequate financing and sustained support from all relevant sectors.

Local knowledge and Customary Water Management Practices can Strengthen Environmental Flow Planning, Implementation, and Sustainable Outcomes

Ecological, hydrological, and social interactions underpin the economies of riparian communities and their cultural heritage. All societies have developed institutions (laws, norms, values) that draw on such knowledge to govern systems of water access, use, and management. The full and equal participation of all cultures, and respect for their rights, responsibilities, and systems of governance in environmental flow decisions can strengthen sustainable outcomes for cultures, economies, livelihoods, and well-being.

Climate Change Increases the Risk of Aquatic Ecosystem Degradation and Intensifies the Urgency for Action to Implement Environmental Flows

Climate change is introducing increasing uncertainty about water availability and regimes of water flow, temperature, chemistry, and sediment fluxes, and causing biota to shift habitat. Climate change compounds human water security challenges, and will intensify the need for, and pressures on, environmental water. Conventional twentieth century water management approaches, heavily based on supply-side engineering interventions, are no longer sufficient for a world with rapidly shifting hydrology. These factors heighten the need for urgent and co-ordinated action to assess options for environmental flow management, and to implement optimal water management solutions for ecosystems, cultures, economies, sustainable livelihoods, and human well-being.

Global Action Agenda on Environmental Flows (2018)

The Brisbane Declaration on Environmental Flows (2018) calls upon all governments, development banks, donors, water and energy associations, multilateral and bilateral institutions, community-based organizations, research institutions, indigenous groups and the private sector across the globe to commit to the following actionable recommendations (**Table A1**) for protecting and restoring environmental flows as a central element of water resources management, and as a foundation for achievement of the water-related Sustainable Development Goals (SDGs).

TABLE A1 | The Brisbane Declaration on Environmental Flows (2018) and supporting actionable recommendations of the Global Action Agenda on Environmental Flows (2018).

Declaration statements	Leadership and governance	Management	Research
E-flows are essential to protect and restore biodiversity, aquatic ecosystems, and the ecosystem services they provide for all societies	Develop and implement government programs to support provision of e-flows to freshwater-dependent ecosystems, including Groundwater Dependent Ecosystems (GDEs) [1,2] Develop and implement government e-flow programs to support achievement of water-related Sustainable Development Goals (SDGs)[1]	Develop and implement e-flow programs that integrate surface and groundwater processes into e-flow planning, assessment, monitoring, and management[3,4,5] Integrate e-flows into programs and projects designed to support achievement of water-related Sustainable Development Goals (SDGs)[1,6]	Quantify flow-ecology relationships and ecosystem services for all aquatic ecosystems that depend on fresh water, including GDEs[3,4,5] Demonstrate ecological, economic, and societal benefits of e-flows and healthy freshwater-dependent ecosystems in programs and projects that support water-related Sustainable Development Goals (SDGs)[1,66]
E-flows are critical to protect and restore the world's cultural and natural heritage	Develop and implement government programs to generate awareness of cultural heritage values, knowledge, and attachments to freshwater-dependent ecosystems[6,7,8]	Integrate cultural heritage values, knowledge, and attachments to freshwater-dependent ecosystems into e-flow assessment, implementation, monitoring, and adaptive management[6,7,8]	Improve understanding and quantify relationships between e-flows, healthy aquatic ecosystems, and cultural heritage values, and attachments to freshwater-dependent ecosystems [6,7]
E-flows have been compromised and today many aquatic systems around the world are at risk	Develop and implement government programs to protect and restore freshwater ecosystems. Protect healthy freshwater-dependent ecosystems as early as possible[8] Establish programs to implement e-flows during the planning stage of new dams and other water infrastructure[2,8,9]	Apply systematic planning tools to achieve cost-effective protection and restoration of healthy freshwater ecosystem[8,9,11] Base protection and restoration of e-flows on scientific and local knowledge within an adaptive management framework that balances human and ecological water requirements[2,10]	Identify obstacles to implementation of e-flows in different world settings. Improve systematic planning tools and trade-off processes that can guide the location, design, and operation of new dams/other water infrastructure, for social-ecological benefit[9,10,11]
Implementation of e-flows requires a complementary suite of policy, legislative, regulatory, financial, scientific, and cultural norms and values to ensure effective delivery and beneficial outcomes	Develop and implement a legal basis for regulating water use, e-flows, water rights, and licenses, including recognition of cultural heritage values, knowledge, and customary relationships with water[2,7,12] Develop and implement policies and programs to position e-flows as an integral component of water, food, and energy security objectives and water-related SDGs[6,12]	Establish environmental water allocation mechanisms appropriate to basin conditions and governance structures[12] Establish a system to manage consumptive water uses at basin and local scales[12] Utilize basin and system-scale infrastructure planning, design, and operation to protect and enable e-flows even where dams and other types of water infrastructure are needed, as well as in cases of infrastructure retrofitting and decommissioning[11,13]	Investigate existing, and propose new, mechanisms for integrating e-flows implementation in broader water and related resource management system[13,14,17] Research effective design, monitoring, and reporting of e-flow implementation projects and programs, treating them as experiments where feasible[10,14,,15]

(Continued)

TABLE A1 | Continued

Declaration statements	Leadership and governance	Management	Research
	Provide sustained funding to effectively plan, design, implement, monitor, and adaptively manage e-flows[10,14] Provide sustained funding for research and training to enhance understanding of aquatic ecosystem functioning, e-flow planning, assessment, implementation, monitoring, and adaptive management[3,10,12]	Ensure that water management professionals have sufficient technical capacity and knowledge to incorporate environmental flow approaches into water resource management plans, implementation, monitoring, and adaptive management	Establish centers of excellence for research and training to enhance understanding of aquatic ecosystem functioning, e-flow planning, assessment, implementation, monitoring, and adaptive management
Local knowledge and customary water management practices can strengthen e-flow planning, implementation, and sustainable outcomes	Develop and implement arrangements for full and equal participation, and respect for the rights, responsibilities and systems of governance of all cultures and stakeholders in e-flow planning, assessment, implementation, monitoring, and adaptive management[7,15,18]	Empower and ensure the full and equal participation, and respect for the rights, responsibilities and systems of governance, of all cultures and stakeholders in e-flow planning, assessment, implementation, monitoring, and adaptive management[7,15,18]	Co-develop best-practice models to ensure full and equal participation, and respect for the responsibilities, rights and systems of governance of all cultures and stakeholders in e-flow planning, assessment, implementation, monitoring, and adaptive management[7,15,18]
Climate change increases the risk of aquatic ecosystem degradation and intensifies the urgency for action to implement e-flows	Develop and implement flexible governance and management arrangements that enable consideration of climatic and other environmental regime change implications for e-flows and ecosystems. Establish programs to implement adjustments to e-flows in aquatic ecosystems impacted by changing flow and other environmental regimes[2,19,20]	Where climate change may further disrupt e-flows and social-ecological systems, adapt existing approaches to maintain/restore ecological resilience and societal benefits[16,17,20] Monitor ecological and societal outcomes of e-flows in relation to changing flow and other environmental regimes, and adjust implementation plans accordingly[10,20]	Conduct long-term studies of freshwater-dependent ecosystem adjustments and societal responses to changing flow and other environmental regimes in areas experiencing shifts in climate, human demographic patterns, and demands for water[16,18,20] Research new approaches to maintain/restore ecological resilience and societal benefits in such areas[17,19,20]

INFORMATION SOURCES:1, (UN, 2015); 2, (Horne et al., 2017a); 3, (Poff et al., 2010); 4, (Gleeson and Richter, 2017); 5, (Bunn and Arthington, 2002); 6, (Bunn, 2016); 7, (Jackson, 2017); 8, (Finlayson et al., 2017); 9, (Hermoso et al., 2012); 10, (Webb et al., 2017); 11, (Winemiller et al., 2016); 12, (Horne et al., 2017c); 13, (Harwood et al., 2017); 14, (Thomas, 2017); 15, (Poff et al., 2003); 16, (Davies et al., 2014); 17, (Pahl-Wostl et al., 2013); 18, (Conallin et al., 2017); 19, (Rockström et al., 2014); 20, (Poff, 2018).

APPENDIX 2

The Brisbane Declaration (2007)

Environmental Flows[1] are Essential for Freshwater Ecosystem Health and Human Well-Being

This declaration presents summary findings and a global action agenda that address the urgent need to protect rivers globally, as proclaimed at the 10th International River*symposium* and International Environmental Flows Conference, held in Brisbane, Australia, on 3–6 September 2007. The conference was attended by more than 750 scientists, economists, engineers, resource managers, and policy makers from more than 50 countries.

Key Findings Include

Freshwater Ecosystems Are the Foundation of our Social, Cultural, and Economic Well-Being

Healthy freshwater ecosystems—rivers, lakes, floodplains, wetlands, and estuaries—provide clean water, food, fiber, energy, and many other benefits that support economies and livelihoods around the world. They are essential to human health and well-being.

Freshwater Ecosystems Are Seriously Impaired and Continue to Degrade at Alarming Rates

Aquatic species are declining more rapidly than terrestrial and marine species. As freshwater ecosystems degrade, human communities lose important social, cultural, and economic benefits; estuaries lose productivity; invasive plants and animals flourish; and the natural resilience of rivers, lakes, wetlands, and estuaries weakens. The severe cumulative impact is global in scope.

Water Flowing to the Sea is *Not* Wasted

Fresh water that flows into the ocean nourishes estuaries, which provide abundant food supplies, buffer infrastructure against storms and tidal surges, and dilute and evacuate pollutants.

Flow alteration Imperils Freshwater and Estuarine Ecosystems

These ecosystems have evolved with, and depend upon, naturally variable flows of high-quality fresh water. Greater attention to environmental flow needs must be exercised when attempting to manage floods; supply water to cities, farms, and industries; generate power; and facilitate navigation, recreation, and drainage.

Environmental Flow Management

Environmental flow management provides the water flows needed to sustain freshwater and estuarine ecosystems in coexistence with agriculture, industry, and cities. The goal of environmental flow management is to restore and maintain the socially valued benefits of healthy, resilient freshwater ecosystems through participatory decision making informed by sound science. Ground-water and floodplain management are integral to environmental flow management.

Climate Change Intensifies the Urgency

Sound environmental flow management hedges against potentially serious and irreversible damage to freshwater ecosystems from climate change impacts by maintaining and enhancing ecosystem resiliency.

Progress has Been Made, but Much More Attention is Needed

Several governments have instituted innovative water policies that explicitly recognize environmental flow needs. Environmental flow needs are increasingly being considered in water infrastructure development and are being maintained or restored through releases of water from dams, limitations on ground-water and surface-water diversions, and management of land-use practices. Even so, the progress made to date falls far short of the global effort needed to sustain healthy freshwater ecosystems and the economies, livelihoods, and human well-being that depend upon them.

Global Action Agenda

The delegates to the 10th International River*symposium* and Environmental Flows Conference call upon all governments, development banks, donors, river basin organizations, water and energy associations, multilateral, and bilateral institutions, community-based organizations, research institutions, and the private sector across the globe to commit to the following actions for restoring and maintaining environmental flows:

Estimate Environmental Flow Needs Everywhere Immediately

Environmental flow needs are currently unknown for the vast majority of freshwater and estuarine ecosystems. Scientifically credible methodologies quantify the variable—not just minimum—flows needed for each water body by *explicitly* linking environmental flows to specific ecological functions and social values. Recent advances enable rapid, region-wide, scientifically credible environmental flow assessments.

Integrate Environmental Flow Management Into Every Aspect of Land and Water Management

Environmental flow assessment and management should be a basic requirement of Integrated Water Resource Management (IWRM); environmental impact assessment (EIA); strategic environmental assessment (SEA); infrastructure and industrial development and certification; and land-use, water-use, and energy-production strategies.

Establish Institutional Frameworks

Consistent integration of environmental flows into land and water management requires laws, regulations, policies and programs that: (1) recognize environmental flows as integral to sustainable water management, (2) establish precautionary limits on allowable depletions and alterations of natural flow, (3) treat ground water and surface water as a single hydrologic

[1] *Environmental flows* describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.

resource, and (4) maintain environmental flows across political boundaries.

Integrate Water *Quality* Management

Minimizing and treating wastewater reduces the need to maintain un-naturally high streamflow for dilution purposes. Properly-treated wastewater discharges can be an important source of water for meeting environmental flow needs.

Actively Engage all Stakeholders

Effective environmental flow management involves all potentially affected parties and relevant stakeholders and considers the full range of human needs and values tied to freshwater ecosystems. Stakeholders suffering losses of ecosystem service benefits should be identified and properly compensated in development schemes.

Implement and Enforce Environmental Flow Standards

Expressly limit the depletion and alteration of natural water flows according to physical and legal availability, and accounting for environmental flow needs. Where these needs are uncertain, apply the precautionary principle and base flow standards on best available knowledge. Where flows are already highly altered, utilize management strategies, including water trading, conservation, floodplain restoration, and dam re-operation, to restore environmental flows to appropriate levels.

Identify and Conserve a Global Network of Free-Flowing Rivers

Dams and dry reaches of rivers prevent fish migration and sediment transport, physically limiting the benefits of environmental flows. Protecting high-value river systems from development ensures that environmental flows and hydrological connectivity are maintained from river headwaters to mouths. It is far less costly and more effective to protect ecosystems from degradation than to restore them.

Build Capacity

Train experts to scientifically assess environmental flow needs. Empower local communities to participate effectively in water management and policy-making. Improve engineering expertise to incorporate environmental flow management in sustainable water supply, flood management, and hydropower generation.

Learn by Doing

Routinely monitor relationships between flow alteration and ecological response before and during environmental flow management, and refine flow provisions accordingly. Present results to all stakeholders and to the global community of environmental flow practitioners.